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Title of the Invention

Alloy Type Thermal Fuse and Material for a Thermal
Fuse Element

5 Background of the Invention

1. Field of the Invention

[0001]

The present invention relates to a material for a Bi-In-Sn thermal fuse element, and also to an alloy type thermal fuse.

[0002]

An alloy type thermal fuse is widely used as a thermoprotector for an electrical appliance or a circuit element, for example, a semiconductor device, a capacitor, or a resistor.

Such an alloy type thermal fuse has a configuration in which an alloy of a predetermined melting point is used as a fuse element, the fuse element is bonded between a pair of lead conductors, a flux is applied to the fuse element, and the flux-applied fuse element is sealed by an insulator.

The alloy type thermal fuse has the following operation mechanism.

The alloy type thermal fuse is disposed so as to thermally contact an electrical appliance or a circuit element

which is to be protected. When the electrical appliance or the circuit element is caused to generate heat by any abnormality, the fuse element alloy of the thermal fuse is melted by the generated heat, and the molten alloy is divided and spheroidized because of the wettability with respect to the lead conductors or electrodes under the coexistence with the activated flux that has already melted. The power supply is finally interrupted as a result of advancement of the spheroid division. The temperature of the appliance is lowered by the power supply interruption, and the divided molten alloys are solidified, whereby the non-return cut-off operation is completed.

[0003]

Usually, a technique in which an alloy composition having a narrow solid-liquid coexisting region between the solidus and liquidus temperatures, and ideally a eutectic composition is used as such a fuse element is usually employed, so that the fuse element is fused off at approximately the liquidus temperature (in a eutectic composition, the solidus temperature is equal to the liquidus temperature). In a fuse element having an alloy composition in which there is a solid-liquid coexisting region, namely, there is the possibility that the fuse element is fused off at an uncertain temperature in the solid-liquid coexisting region. When an alloy composition has a wide solid-liquid

coexisting region, the uncertain temperature width in which a fuse element is fused off in the solid-liquid coexisting region becomes large, and the operating temperature is largely dispersed. In order to reduce the dispersion, therefore, the technique in which an alloy composition having a narrow solid-liquid coexisting region, and ideally a eutectic composition is used as such a fuse element is usually employed.

[0004]

Because of increased awareness of environment conservation, the trend to prohibit the use of materials harmful to a living body is recently growing as a requirement on an alloy type thermal fuse. Also an element for such a thermal fuse is strongly requested not to contain a harmful material.

2. Description of the Prior Art

[0005]

As an alloy composition for such a thermal fuse element, known is a Bi-In-Sn system. Conventionally, known are alloy compositions such as that of 47 to 49% Sn, 51 to 53% In, and the balance Bi (Japanese Patent Application Laying-Open No. 56-114237), that of 42 to 44% Sn, 51 to 53% In, and 4 to 6% Bi (Japanese Patent Application Laying-Open No. 59-8229), that of 44 to 48% Sn, 48 to 52% In, and 2 to

6% Bi (Japanese Patent Application Laying-Open No. 3-236130), that of 0.3 to 1.5% Sn, 51 to 54% In, and the balance Bi (Japanese Patent Application Laying-Open No. 6-325670), that of 33 to 43% Sn, 0.5 to 10% In, the balance
5 Bi (Japanese Patent Application Laying-Open No. 2001-266723), that of 40 to 46% Sn, 7 to 12% Bi, the balance In (Japanese Patent Application Laying-Open No. 2001-266724), that of 2.5 to 10% Sn, 25 to 35% Bi, the balance In (Japanese Patent Application Laying-Open No. 2001-291459), and
10 that of 1 to 15% Sn, 20 to 33% Bi, and the balance In (Japanese Patent Application Laying-Open No. 2001-325867).

[0006]

When the liquidus phase diagram of a ternary Bi-In-Sn alloy is obtained, there are a binary eutectic point of
15 52In-48Sn and a ternary eutectic point of 21Sn-48In-31Bi, and the binary eutectic curve which elongates from the binary eutectic point toward the ternary eutectic point passes approximately through a frame of 24 to 47 Sn, 50 to 47 In, and 0 to 28 Bi.

20 As well known, when a heat energy is applied to an alloy at a constant rate, the heat energy is spent only in raising the temperature of the alloy as far as the solidus or liquidus state is maintained. When the alloy starts to melt, however, the temperature is raised while part of the
25 energy is spent in the phase change. When the liquidifica-

tion is then completed, the heat energy is spent only in temperature rise while the phase state is unchanged. The temperature rise/heat energy state can be obtained by a differential scanning calorimetry analysis [in which a reference specimen (unchanged) and a measurement specimen are housed in an N₂ gas-filled vessel, an electric power is supplied to a heater of the vessel to heat the samples at a constant rate, and a variation of the heat energy input amount due to a state change of the measurement specimen is detected by a differential thermocouple, and which is called a DSC].

[0007]

Results of the DSC measurement are varied depending on the alloy composition. The inventor measured and eagerly studied DSCs of Bi-In-Sn alloys of various compositions. As a result, depending on the composition, the DSCs show melting characteristics of the patterns shown in (A) to (D) of Fig. 11, and unexpectedly found the following phenomenon. The pattern of (A) of Fig. 11 is in a specific region which is separated from the binary eutectic curve. When a Bi-In-Sn alloy of this melt pattern is used as fuse elements, the fuse elements can be concentrically fused off in the vicinity of the maximum endothermic peak.

[0008]

The pattern of (A) of Fig. 11 will be described. At

the solidus temperature a, an alloy starts to be liquified (melted). In accordance with progress of the liquidification, the absorption amount of heat energy is increased, and reaches the maximum at a peak p. After passing the
5 point, the absorption amount of heat energy is gradually reduced, and becomes zero at the liquidus temperature b, thereby completing the liquidification. Thereafter, the temperature is raised in the state of the liquidus phase.

The reason why a division operation of the fuse ele-
10 ment occurs in the vicinity of the maximum endothermic peak p is estimated as follows. A Bi-In-Sn composition showing such a melting characteristic contains large amounts of In and Sn, and hence exhibits excellent wettability in the solid-liquid coexisting region in the vicinity of the maxi-
15 mum endothermic peak p in which the liquidus phase has not yet been completely established. Therefore, spheroid division occurs before a state exceeding the solid-liquid coexisting region is attained.

In the melt pattern of (C) of Fig. 11, the heat energy
20 is slowly absorbed, and the wettability is not abruptly changed. Therefore, the point of a division operation of the fuse element is not determined in a narrow range. In the melt pattern of (D) of Fig. 11, there are plural endothermic peaks. At any one of the endothermic peaks, a di-
25 vision operation of the fuse element may probably occur.

In both (C) and (D) of Fig. 11, the point of a division operation of the fuse element cannot be concentrated into a narrow range.

[0009]

5 A thermal fuse is requested to have the overload characteristic and the dielectric breakdown characteristic.

 The overload characteristic means external stability in which, even when a thermal fuse operates in an raised ambient temperature under the state where a current and a
10 voltage of a specified degree are applied to the thermal fuse, the fuse is not damaged or does not generate an arc, a flame, or the like, thereby preventing a dangerous condition from occurring. The dielectric breakdown characteristic means insulation stability in which, even at a specified
15 high voltage, a thermal fuse that has operated does not cause dielectric breakdown and the insulation can be maintained.

[0010]

 A method of evaluating the overload characteristic and
20 the dielectric breakdown characteristic is specified in IEC (International Electrotechnical Commission) Standard 60691 which is a typical standard, as follows. When, while a rated voltage $\times 1.1$ and a rated current $\times 1.5$ are applied to a thermal fuse, the temperature is raised at a rate of 2
25 ± 1 K/min. to cause the thermal fuse to operate, the fuse

does not generate an arc, a flame, or the like, thereby preventing a dangerous condition from occurring. After the thermal fuse operates, even when a voltage of the rated voltage $\times 2 + 1,000$ V is applied for 1 min. between a metal foil wrapped around the body of the fuse and lead conductors, and, even when a voltage of the rated voltage $\times 2$ is applied for 1 min. between the lead conductors, discharge or dielectric breakdown does not occur.

The inventor ascertained that, in a Bi-In-Sn alloy composition having a melt pattern such as that of (A) of Fig. 11, excellent overload characteristic and dielectric breakdown characteristic are obtained.

In the melt pattern of (B) of Fig. 11 which is a pattern of a composition in the vicinity of the binary eutectic curve, the solidus temperature a and the liquidus temperature b are close to each other, and the requirement of a fuse element by the above-mentioned usual technique is satisfied. However, it has been found that there is a problem in the overload characteristic and the dielectric breakdown characteristic.

The reason of this is estimated as follows. Since the fuse element has a narrow solid-liquid coexisting region, the alloy during energization and temperature rise is instantly changed from the solid phase to the liquid phase, thereby causing an arc to be easily generated during an op-

eration. When an arc is generated, a local and sudden temperature rise occurs. As a result, the flux is vaporized to raise the internal pressure, or the flux is charred, so that physical destruction easily occurs. In addition to
5 the above, the molten alloy or the charred flux is intensely scattered as a result of an energizing operation. This scattering is more intense, as the surface tension is higher. Therefore, physical destruction by arc generation due to reconnection between charred flux portions easily
10 occurs. Moreover, the insulation distance is shortened by the scattered alloy or the charred flux, so that dielectric breakdown is easily caused by reconnection when a voltage is applied after an operation.

15 Summary of the Invention

[0011]

It is an object of the invention to, based on the finding, provide an alloy type thermal fuse in which a fuse element of a Bi-In-Sn alloy is used, and which has excellent
20 overload characteristic and dielectric breakdown characteristic.

It is a further object of the invention to lower the specific resistance of a fuse element and thin the fuse element, thereby enabling an alloy type thermal fuse to be
25 thinned and miniaturized.

[0012]

The material for a thermal fuse element of a first aspect of the invention has an alloy composition in which Sn is larger than 46% and 70% or smaller, Bi is 1% or larger
5 and 12% or smaller, and In is 18% or larger and smaller than 48%.

[0013]

In the material for a thermal fuse element of a second aspect of the invention, 0.1 to 3.5 weight parts of one, or
10 two or more elements selected from the group consisting of Ag, Au, Cu, Ni, Pd, Pt, Sb, Ga, and Ge are added to 100 weight parts of the alloy composition of the first aspect of the invention.

[0014]

15 The materials for a thermal fuse element of the first and second aspects of the invention are allowed to contain inevitable impurities which are produced in productions of metals of raw materials and also in melting and stirring of the raw materials, and which exist in an amount that does
20 not substantially affect the characteristics. In the alloy type thermal fuses, a minute amount of a metal material or a metal film material of the lead conductors or the film electrodes is caused to inevitably migrate into the fuse element by solid phase diffusion, and, when the character-
25 istics are not substantially affected, allowed to exist as

inevitable impurities.

[0015]

In the alloy type thermal fuse of a third aspect of the invention, the material for a thermal fuse element of the first or second aspect of the invention is used as a
5 fuse element.

[0016]

The alloy type thermal fuse of a fourth aspect of the invention is characterized in that, in the alloy type thermal fuse of the third aspect of the invention, the fuse
10 element contains inevitable impurities.

[0017]

The alloy type thermal fuse of a fifth aspect of the invention is an alloy type thermal fuse in which, in the alloy type thermal fuse of the third or fourth aspect of the invention, the fuse element is connected between lead
15 conductors, and at least a portion of each of the lead conductors which is bonded to the fuse element is covered with an Sn or Ag film.

20 [0018]

The alloy type thermal fuse of a sixth aspect of the invention is an alloy type thermal fuse in which, in the alloy type thermal fuse of any one of the third to fifth of the invention, lead conductors are bonded to ends of the
25 fuse element, respectively, a flux is applied to the fuse

element, the flux-applied fuse element is passed through a cylindrical case, gaps between ends of the cylindrical case and the lead conductors are sealingly closed, ends of the lead conductors have a disk-like shape, and ends of the fuse element are bonded to front faces of the disks.

[0019]

The alloy type thermal fuse of a seventh aspect of the invention is an alloy type thermal fuse in which, in the alloy type thermal fuse of the third or fourth aspect of the invention, a pair of film electrodes are formed on a substrate by printing conductive paste containing metal particles and a binder, the fuse element is connected between the film electrodes, and the metal particles are made of a material selected from the group consisting of Ag, Ag-Pd, Ag-Pt, Au, Ni, and Cu.

[0020]

The alloy type thermal fuse of an eighth aspect of the invention is an alloy type thermal fuse in which, in the alloy type thermal fuse of any one of the third to seventh aspects of the invention, a heating element for fusing off the fuse element is additionally disposed.

[0021]

The alloy type thermal fuse of a ninth aspect of the invention is an alloy type thermal fuse in which, in the alloy type thermal fuse of any one of the third to fifth

aspects of the invention, a pair of lead conductors are partly exposed from one face of an insulating plate to another face, the fuse element is connected to the lead conductor exposed portions, and the other face of the insulating plate is covered with an insulating material.

[0022]

The alloy type thermal fuse of a tenth aspect of the invention is an alloy type thermal fuse in which, in the alloy type thermal fuse of any one of the third to fifth aspects of the invention, the fuse element connected between a pair of lead conductors is sandwiched between insulating films.

Brief Description of the Drawings

Fig. 1 is a view showing an example of the alloy type thermal fuse of the invention;

Fig. 2 is a view showing another example of the alloy type thermal fuse of the invention;

Fig. 3 is a view showing a further example of the alloy type thermal fuse of the invention;

Fig. 4 is a view showing a still further example of the alloy type thermal fuse of the invention;

Fig. 5 is a view showing a still further example of the alloy type thermal fuse of the invention;

Fig. 6 is a view showing a still further example of

the alloy type thermal fuse of the invention;

Fig. 7 is a view showing a still further example of the alloy type thermal fuse of the invention;

Fig. 8 is a view showing an alloy type thermal fuse of the cylindrical case type and its operation state;

Fig. 9 is a view showing a still further example of the alloy type thermal fuse of the invention;

Fig. 10 is a view showing a DSC curve of a fuse element of Example 1; and

Fig. 11 is a view showing various melt patterns of a ternary Sn-In-Bi alloy.

Detailed Description of the Preferred Embodiments

[0023]

In the invention, a fuse element of a circular wire or a flat wire is used. The outer diameter or the thickness is set to 100 to 800 μm , preferably, 300 to 600 μm .

[0024]

The reason why, in the first aspect of the invention, the fuse element has an alloy composition of $46\% < \text{weight of Sn} \leq 70\%$, $1\% \leq \text{weight of Bi} \leq 12\%$, and $18\% \leq \text{weight of In} < 48\%$ is as follows. The overlap with the above-mentioned known alloy compositions can be eliminated. The alloy fusing characteristic of the pattern shown in (A) of Fig. 11 in which, although separated from the binary eutec-

tic curve from the binary eutectic point of 52In-48Sn toward the ternary eutectic point of 21Sn-48In-31Bi in the liquidus phase diagram of a ternary Bi-In-Sn alloy, a division operation of the fuse element can be definitely performed in the vicinity of the maximum endothermic peak can be obtained.

In order to eliminate the overlap with the known Bi-In-Sn compositions of the conventional thermal fuse elements, the range in which Sn is 46% or smaller and In is larger than 50% is excluded. The range in which Bi is larger than 12% and smaller than 1%, Sn is larger than 70%, and In is smaller than 18% is excluded because of the following reasons. The range overlaps with the range set forth in another patent application of the assignee of the present invention. Although the solid-liquid coexisting region may be wide, a result of a DSC measurement is the pattern of (C) or (D) of Fig. 11 to expedite dispersion of the operating temperature. The specific resistance is excessively increased. It is difficult to set a holding temperature (operating temperature - 20°C) which will be described later, to be equal to lower than the solidus temperature.

[0025]

The preferred range is $50\% \leq \text{weight of Sn} \leq 60\%$, $5\% \leq \text{weight of Bi} \leq 10\%$, and $35\% \leq \text{weight of In} \leq 45\%$. The ref-

erence composition is 55% Sn, 8% Bi, and 37% In. The composition has a liquidus temperature of about 157°C, and a solidus temperature of about 84°C. Fig. 10 shows a result of a DSC measurement at a temperature rise rate of 5°C/min.

5 There is a single maximum endothermic peak at a temperature of about 97°C.

[0026]

The fuse elements of the invention have the following performances.

10 (1) In the endothermic behavior in the melting process, a single maximum endothermic peak exists, and the heat absorption amount difference at the peak is very larger than the heat absorption amount difference in another portion of the endothermic process. The total amount of In and Sn
15 which have a smaller surface tension is larger than the amount of Bi having a larger surface tension. Therefore, the wettability of the solid-liquid coexisting region at the maximum endothermic peak is sufficiently improved even before the completion of the liquidification, so that spheroid
20 roid division of the thermal fuse element can be performed in the vicinity of the maximum endothermic peak.

(2) Therefore, dispersion of the operating temperature among thermal fuses can be set to be within an allowable range of $\pm 5^{\circ}\text{C}$.

25 (3) When self-heating due to a passing current occurs in a

fuse element, a thermal fuse operates at a lower environmental temperature than that in the case of no load. In a thermal fuse, therefore, it is required to set a maximum holding temperature at which, even when a rated current
5 continues to flow for 168 hours, the fuse does not operate.

The maximum holding temperature is called the holding temperature, and usually set to (operating temperature - 20°C).

In this case, the solidus temperature is requested to be equal to or higher than the holding temperature. The fuse
10 elements satisfy the requirement.

(4) Since In and Sn are contained in a relatively large amount, the fuse elements are provided with sufficient ductility required for drawing into a thin wire, so that drawing into a thin wire of 200 to 300 $\mu\text{m}\phi$ is enabled.

15 (5) Excellent overload characteristic and dielectric breakdown characteristic can be assured. As described above, in a fuse element of the pattern shown in (B) of Fig. 11, the solid-liquid coexisting region is narrow, and hence the alloy during energization and temperature rise is instantly
20 changed from the solid phase to the liquid phase, thereby causing an arc to be easily generated during an operation. When an arc is generated, a local and sudden temperature rise occurs. As a result, the flux is vaporized to raise the internal pressure, or the flux is charred. In addition
25 to the above, the molten alloy or the charred flux is in-

tensely scattered as a result of a sudden energizing operation. Therefore, physical destruction such as crack generation due to a local and sudden internal pressure rise, or reconnection between charred flux portions easily occurs. Moreover, the insulation distance is shortened by the scattered alloy or the charred flux. Therefore, dielectric breakdown is easily caused by reconnection when a voltage is applied after an operation. By contrast, In a fuse element of the alloy composition of the invention, the alloy composition is considerably separated from the binary eutectic curve, and has a fairly wide solid-liquid coexisting region. The total content of In and Sn which have a smaller surface tension is larger than the content of Bi having a larger surface tension. Therefore, the fuse element is divided in a wide solid-liquid coexisting state even during energization and temperature rise, and hence the generation of an arc immediately after an operation can be satisfactorily suppressed. Because of a synergistic effect of the sufficient suppression of the arc generation immediately after an operation, and the reduced surface tension due to the small content of Bi, the above-mentioned physical destruction does not occur even in an overload test according to the nominal rating, so that the insulation resistance after an operation can be maintained to be sufficiently high and an excellent dielectric breakdown

characteristic can be assured.

[0027]

In the invention, 0.1 to 3.5 weight parts of one, or two or more elements selected from the group consisting of Ag, Au, Cu, Ni, Pd, Pt, Sb, Ga, and Ge are added to 100 weight parts of the alloy composition, in order to reduce the specific resistance of the alloy and improve the mechanical strength. When the addition amount is smaller than 0.1 weight parts, the effects cannot be sufficiently attained, and, when the addition amount is larger than 3.5 weight parts, the above-mentioned melting characteristic is hardly maintained.

With respect to a drawing process, further enhanced strength and ductility are provided so that drawing into a thin wire of 100 to 300 $\mu\text{m}\phi$ can be easily conducted. When a fuse element contains a relatively large amount of In, the cohesive force is considerably high. Even when the fuse element is insufficiently welded or bonded to lead conductors or the like, therefore, a superficial appearance in which the element is bonded is produced. The addition of the element(s) reduces the cohesive force, so that this defect can be eliminated, and the accuracy of the acceptance criterion in a test after welding can be improved.

It is known that a to-be-bonded material such as a metal material of the lead conductors, a thin-film mate-

rial, or a particulate metal material in the film electrode migrates into the fuse element by solid phase diffusion. When the same element as the to-be-bonded material, such as Ag, Au, Cu, or Ni is previously added to the fuse element, 5 the migration can be suppressed. Therefore, an influence of the to-be-bonded material which may originally affect the characteristics (for example, Ag, Au, or the like causes local reduction or dispersion of the operating temperature due to the lowered melting point, and Cu, Ni, or 10 the like causes dispersion of the operating temperature or an operation failure due to an increased intermetallic compound layer formed in the interface between different phases) is eliminated, and the thermal fuse can be assured to normally operate, without impairing the function of the 15 fuse element.

[0028]

The fuse element of the alloy type thermal fuse of the invention can be usually produced by a method in which a billet is produced, the billet is shaped into a stock wire 20 by an extruder, and the stock wire is drawn by a dice to a wire. The outer diameter is 100 to 800 $\mu\text{m}\phi$, preferably, 300 to 600 $\mu\text{m}\phi$. The wire can be finally passed through calender rolls so as to be used as a flat wire.

Alternatively, the fuse element may be produced by the 25 rotary drum spinning method in which a cylinder containing

cooling liquid is rotated, the cooling liquid is held in a layer-like manner by a rotational centrifugal force, and a molten material jet ejected from a nozzle is introduced into the cooling liquid layer to be cooled and solidified, thereby obtaining a thin wire member.

In the production, the alloy composition is allowed to contain inevitable impurities which are produced in productions of metals of raw materials and also in melting and stirring of the raw materials.

[0029]

The invention may be implemented in the form of a thermal fuse serving as an independent thermoprotector. Alternatively, the invention may be implemented in the form in which a thermal fuse element is connected in series to a semiconductor device, a capacitor, or a resistor, a flux is applied to the element, the flux-applied fuse element is placed in the vicinity of the semiconductor device, the capacitor, or the resistor, and the fuse element is sealed together with the semiconductor device, the capacitor, or the resistor by means of resin mold, a case, or the like.

[0030]

Fig. 1 shows an alloy type thermal fuse of the cylindrical case type according to the invention. A fuse element 2 made of a material for a thermal fuse element according to claim 1 or 2 is connected between a pair of lead

conductors 1 by, for example, welding. A flux 3 is applied to the fuse element 2. The flux-applied fuse element is passed through an insulating tube 4 which is excellent in heat resistance and thermal conductivity, for example, a ceramic tube. Gaps between the ends of the insulating tube 4 and the lead conductors 1 are sealingly closed by a sealing agent 5 such as a cold-setting epoxy resin.

[0031]

Fig. 2 shows a fuse of the radial case type. A fuse element 2 made of a material for a thermal fuse element according to claim 1 or 2 is connected between tip ends of parallel lead conductors 1 by, for example, welding. A flux 3 is applied to the fuse element 2. The flux-applied fuse element is enclosed by an insulating case 4 in which one end is opened, for example, a ceramic case. The opening of the insulating case 4 is sealingly closed by sealing agent 5 such as a cold-setting epoxy resin.

[0032]

Fig. 3 shows a thin type fuse. In the fuse, strip lead conductors 1 having a thickness of 100 to 200 μm are fixed by, for example, an adhesive agent or fusion bonding to a plastic base film 41 having a thickness of 100 to 300 μm . A fuse element 2 made of a material for a thermal fuse element according to claim 1 or 2 having a diameter of 250 to 500 $\mu\text{m}\phi$ is connected between the strip lead conductors

by, for example, welding. A flux 3 is applied to the fuse element 2. The flux-applied fuse element is sealed by a plastic cover film 42 having a thickness of 100 to 300 μm by means of fixation using, for example, an adhesive agent or ultrasonic fusion bonding.

[0033]

Fig. 4 shows another thin type fuse. In the fuse, strip lead conductors 1 having a thickness of 100 to 200 μm are fixed by, for example, an adhesive agent or fusion bonding to a plastic base film 41 having a thickness of 100 to 300 μm . Portions of the strip lead conductors are exposed to the side of the other face of the base film 41. A fuse element 2 made of a material for a thermal fuse element according to claim 1 or 2 having a diameter of 250 to 500 $\mu\text{m}\phi$ is connected between the exposed portions of the strip lead conductors by, for example, welding. A flux 3 is applied to the fuse element 2. The flux-applied fuse element is sealed by a plastic cover film 42 having a thickness of 100 to 300 μm by means of fixation using, for example, an adhesive agent or ultrasonic fusion bonding.

[0034]

Fig. 5 shows a fuse of the radial resin dipping type. A fuse element 2 made of a material for a thermal fuse element according to claim 1 or 2 is bonded between tip ends of parallel lead conductors 1 by, for example, welding. A

flux 3 is applied to the fuse element 2. The flux-applied fuse element is dipped into a resin solution to seal the element by an insulative sealing agent such as an epoxy resin 5.

5 [0035]

Fig. 6 shows a fuse of the substrate type. A pair of film electrodes 1 are formed on an insulating substrate 4 such as a ceramic substrate by printing conductive paste. Lead conductors 11 are connected respectively to the electrodes 1 by, for example, welding or soldering. A fuse element 2 made of a material for a thermal fuse element according to claim 1 or 2 is bonded between the electrodes 1 by, for example, welding. A flux 3 is applied to the fuse element 2. The flux-applied fuse element is covered with a sealing agent 5 such as an epoxy resin. The conductive paste contains metal particles and a binder. For example, Ag, Ag-Pd, Ag-Pt, Au, Ni, or Cu may be used as the metal particles, and a material containing a glass frit, a thermosetting resin, and the like may be used as the binder.

15 20 [0036]

In the alloy type thermal fuses, in the case where Joule's heat of the fuse element is negligible, the temperature T_x of the fuse element when the temperature of the appliance to be protected reaches the allowable temperature T_m is lower than T_m by 2 to 3°C, and the melting point of

the fuse element is usually set to $[T_m - (2 \text{ to } 3^\circ\text{C})]$.

[0037]

The invention may be implemented in the form in which a heating element for fusing off the fuse element is additionally disposed on the alloy type thermal fuse. As shown in Fig. 7, for example, a conductor pattern 100 having fuse element electrodes 1 and resistor electrodes 10 is formed on the insulating substrate 4 such as a ceramic substrate. by printing conductive paste, and a film resistor 6 is disposed between the resistor electrodes 10 by applying and baking resistance paste (e.g., paste of metal oxide powder such as ruthenium oxide). A fuse element 2 of the first or second aspect of the invention is bonded between the fuse element electrodes 1 by, for example, welding. A flux 3 is applied to the fuse element 2. The flux-applied fuse element 2 and the film resistor 6 are covered with a sealing agent 5 such as an epoxy resin.

In the fuse having an electric heating element, a precursor causing abnormal heat generation of an appliance is detected, the film resistor is energized to generate heat in response to a signal indicative of the detection, and the fuse element is fused off by the heat generation.

The heating element may be disposed on the upper face of an insulating substrate. A heat-resistant and thermal-conductive insulating film such as a glass baked film is

formed on the heating element. A pair of electrodes are disposed, flat lead conductors are connected respectively to the electrodes, and the fuse element is connected between the electrodes. A flux covers a range over the fuse element and the tip ends of the lead conductors. An insulating cover is placed on the insulating substrate, and the periphery of the insulating cover is sealingly bonded to the insulating substrate by an adhesive agent.

[0038]

Among the alloy type thermal fuses, those of the type in which the fuse element is directly bonded to the lead conductors (Figs. 1 to 5) may be configured in the following manner. At least portions of the lead conductors where the fuse element is bonded are covered with a thin film of Sn or Ag (having a thickness of, for example, 15 μm or smaller, preferably, 5 to 10 μm) (by plating or the like), thereby enhancing the bonding strength with respect to the fuse element.

In the alloy type thermal fuses, there is a possibility that a metal material or a thin film material in the lead conductors, or a particulate metal material in the film electrode migrates into the fuse element by solid phase diffusion. As described above, however, the characteristics of the fuse element can be sufficiently maintained by previously adding the same element as the thin

film material into the fuse element.

[0039]

As the flux, a flux having a melting point which is lower than that of the fuse element is generally used. For example, useful is a flux containing 90 to 60 weight parts of rosin, 10 to 40 weight parts of stearic acid, and 0 to 3 weight parts of an activating agent. In this case, as the rosin, a natural rosin, a modified rosin (for example, a hydrogenated rosin, an inhomogeneous rosin, or a polymerized rosin), or a purified rosin thereof can be used. As the activating agent, hydrochloride or hydrobromide of an amine such as diethylamine, or an organic acid such as adipic acid can be used.

[0040]

Among the above-described alloy type thermal fuses, in the fuse of the cylindrical case type, the arrangement in which the lead conductors 1 are placed so as not to be eccentric to the cylindrical case 4 as shown in (A) of Fig. 8 is a precondition to enable the normal spheroid division shown in (B) of Fig. 8. When the lead conductors are eccentric as shown in (C) of Fig. 8, the flux (including a charred flux) and scattered alloy portions easily adhere to the inner wall of the cylindrical case after an operation as shown in (D) of Fig. 8. As a result, the insulation resistance is lowered, and the dielectric breakdown charac-

teristic is impaired.

In order to prevent such disadvantages from being produced, as shown in (A) of Fig. 9, a configuration is effective in which ends of the lead conductors 1 are formed into a disk-like shape d, and ends of the fuse element 2 are bonded to the front faces of the disks d, respectively (by, for example, welding). The outer peripheries of the disks are supported by the inner face of the cylindrical case, and the fuse element 2 is positioned so as to be substantially concentric with the cylindrical case 4 [in (A) of Fig. 9, 3 denotes a flux applied to the fuse element 2, 4 denotes the cylindrical case, 5 denotes a sealing agent such as an epoxy resin, and the outer diameter of each disk is approximately equal to the inner diameter of the cylindrical case]. In this instance, as shown in (B) of Fig. 9, molten portions of the fuse element spherically aggregate on the front faces of the disks d, thereby preventing the flux (including a charred flux) and the scattered alloy portions from adhering to the inner face of the case 4.

[0041]

In the following examples and comparative examples, alloy type thermal fuses of the cylindrical case type having an AC rating of 3 A \times 250 V were used. The fuses have the following dimensions. The outer diameter of a cylindrical ceramic case is 2.5 mm, the thickness of the case is

0.5 mm, the length of the case is 9 mm, a lead conductor is an Sn plated annealed copper wire of an outer diameter of 0.6 mm ϕ , and the outer diameter and length of a fuse element are 0.6 mm ϕ and 3.5 mm, respectively. A compound of 80 weight parts of rosin, 20 weight parts of stearic acid, and 1 weight part of hydrobromide of diethylamine was used as the flux. A cold-setting epoxy resin was used as a sealing agent.

The solidus and liquidus temperatures of a fuse element were measured by a DSC at a temperature rise rate of 5°C/min.

[0042]

Fifty specimens were used. Each of the specimens was immersed into an oil bath in which the temperature was raised at a rate of 1°C/min., while supplying a detection current of 0.1 A to the specimen, and the temperature T₀ of the oil when the current supply was interrupted by blowing-out of the fuse element was measured. A temperature of T₀ - 2°C was determined as the operating temperature of the thermal fuse element.

[0043]

The overload characteristic, and the insulation stability after an operation of a thermal fuse were evaluated on the basis of the overload test method and the dielectric breakdown test method defined in IEC 60691 (the humidity

test before the overload test was omitted).

Specifically, existence of destruction or physical damage at an operation was checked. While a voltage of $1.1 \times$ the rated voltage and a current of $1.5 \times$ the rated current were applied to a specimen, and the thermal fuse was caused to operate by raising the environmental temperature at a rate of (2 ± 1) K/min. Among specimens in which destruction or damage did not occur, those in which the insulation between lead conductors withstood $2 \times$ the rated voltage (500 V) for 1 min., and that between the lead conductors and a metal foil wrapped around the fuse body after an operation withstood $2 \times$ the rated voltage + 1,000 V (1,500 V) for 1 min. were judged acceptable with respect to the dielectric breakdown characteristic, and those in which the insulation resistance between the lead conductors when a DC voltage of $2 \times$ the rated voltage (500 V) was applied was $0.2 \text{ M}\Omega$ or higher, and that between the lead conductors and the metal foil wrapped around the fuse body after an operation was $2 \text{ M}\Omega$ or higher were judged acceptable with respect to the insulation resistance. Acceptance with respect to both the dielectric breakdown characteristic and the insulation characteristic was set as the acceptance criterion for the insulation stability. When 50 specimens were used and all of the 50 specimens were accepted with respect to the insulation stability, the specimens were

evaluated as O, and, when even one of the specimens was not accepted, the specimens were evaluated as x.

[0044]

[Example 1]

5 A composition of 55% Sn, 8% Bi, and the balance In was used as that of a fuse element. A fuse element was produced by a process of drawing to 300 $\mu\text{m}\phi$ under the conditions of an area reduction per dice of 6.5%, and a drawing speed of 50 m/min. As a result, excellent workability was
10 attained while no breakage occurred and no constricted portion was formed.

Fig. 10 shows a result of the DSC measurement. The liquidus temperature was about 157°C, the solidus temperature was about 84°C, and the maximum endothermic peak temperature was about 97°C.
15

The fuse element temperature at an operation of a thermal fuse was $94 \pm 2^\circ\text{C}$. Therefore, it is apparent that the fuse element temperature at an operation of a thermal fuse approximately coincides with the maximum endothermic
20 peak temperature.

Even when the overload test was conducted, the fuse element was able to operate without involving any physical damage such as destruction. With respect to the dielectric breakdown test after the operation, the insulation between
25 lead conductors withstood $2 \times$ the rated voltage (500 V) for

1 min. or longer, and that between the lead conductors and a metal foil wrapped around the fuse body after the operation withstood $2 \times$ the rated voltage + 1,000 V (1,500 V) for 1 min. or longer. Therefore, the fuse element was acceptable. With respect to the insulation characteristic, the insulation resistance between the lead conductors when a DC voltage of $2 \times$ the rated voltage (500 V) was applied was 0.2 M Ω or higher, and that between the lead conductors and the metal foil wrapped around the fuse body after an operation was 2 M Ω or higher. Both the resistances were acceptable, and hence the insulation stability was evaluated as O.

The reason why the overload characteristic and the insulation stability after an operation which are excellent as described above is as follows. Even during the energization and temperature rise, the division of the fuse element is performed in the wide solid-liquid coexisting region. Therefore, the occurrence of an arc immediately after an operation is sufficiently suppressed, and sudden temperature rise hardly occurs. Consequently, pressure rise by vaporization of the flux and charring of the flux due to the temperature rise can be suppressed, and physical destruction does not occur, and scattering and the like of molten alloy or charred flux due to an energizing operation can be satisfactorily suppressed, whereby a sufficient in-

sulation distance can be ensured.

[0045]

[Examples 2 to 5]

The examples were conducted in the same manner as Example 1 except that the alloy composition in Example 1 was changed as listed in Table 1.

The solidus and liquidus temperatures of the examples are shown in Table 1. The fuse element temperatures at an operation are as shown in Table 1, have dispersion of $\pm 4^{\circ}\text{C}$ or smaller, and are in the solid-liquid coexisting region.

In the same manner as Example 1, both the overload characteristic and the insulation stability are acceptable.

The reason of this is estimated as follows. In the same manner as Example 1, the fuse element is divided in a wide solid-liquid coexisting region.

In all the examples, good wire drawability was obtained in the same manner as Example 1.

[Table 1]

Table 1

	Ex. 2	Ex. 3	Ex. 4	Ex. 5
Sn (%)	48	60	65	70
Bi (%)	8	8	8	8
In	Balance	Balance	Balance	Balance
Solidus temperature (°C)	84	84	84	102
Liquidus tempera- ture (°C)	135	165	177	188
Wire drawability	Good	Good	Good	Good
Element temperature at operation (°C)	96 ± 2	89 ± 3	101 ± 4	118 ± 4
Insulation stability	○	○	○	○

[0046]

[Examples 6 to 9]

5 The examples were conducted in the same manner as Ex-
ample 1 except that the alloy composition in Example 1 was
changed as listed in Table 2.

10 The solidus and liquidus temperatures of the examples
are shown in Table 2. The fuse element temperatures at an
operation are as shown in Table 2, have dispersion of ± 4°C
or smaller, and are in the solid-liquid coexisting region.

 In the same manner as Example 1, both the overload
characteristic and the insulation stability are acceptable.

The reason of this is estimated as follows. In the same manner as Example 1, the fuse element is divided in a wide solid-liquid coexisting region.

In all the examples, good wire drawability was obtained in the same manner as Example 1.

[Table 2]

Table 2

	Ex. 6	Ex. 7	Ex. 8	Ex. 9
Sn (%)	55	60	65	70
Bi (%)	1	1	1	1
In	Balance	Balance	Balance	Balance
Solidus temperature (°C)	109	110	112	137
Liquidus temperature (°C)	141	158	179	198
Wire drawability	Good	Good	Good	Good
Element temperature at operation (°C)	111 ± 2	112 ± 2	112 ± 3	149 ± 4
Overload characteristic	Damage, etc. are not observed	Damage, etc. are not observed	Damage, etc. are not observed	Damage, etc. are not observed
Insulation stability	○	○	○	○

[0047]

[Examples 10 to 14]

The examples were conducted in the same manner as Example 1 except that the alloy composition in Example 1 was changed as listed in Table 3.

The solidus and liquidus temperatures of the examples are shown in Table 3. The fuse element temperatures at an operation are as shown in Table 3, have dispersion of $\pm 5^{\circ}\text{C}$ or smaller, and are in the solid-liquid coexisting region.

In the same manner as Example 1, both the overload characteristic and the insulation stability are acceptable.

The reason of this is estimated as follows. In the same manner as Example 1, the fuse element is divided in a wide solid-liquid coexisting region.

In all the examples, good wire drawability was obtained in the same manner as Example 1.

[Table 3]

Table 3

	Ex. 10	Ex. 11	Ex. 12	Ex. 13	Ex. 14
Sn (%)	48	55	60	65	70
Bi (%)	12	12	12	12	12
In	Balance	Balance	Balance	Balance	Balance
Solidus					
temperature	61	61	82	99	122
(°C)					
Liquidus					
tempera-	143	157	170	184	193
ture (°C)					
Wire					
drawability	Good	Good	Good	Good	Good
Element					
temperature					
at opera-	78 ± 3	77 ± 4	85 ± 4	114 ± 4	137 ± 5
tion (°C)					
Overload	Damage,	Damage,	Damage,	Damage,	Damage,
character-	etc. are	etc. are	etc. are	etc. are	etc. are
istic	not ob-	not ob-	not ob-	not ob-	not ob-
	served	served	served	served	served
Insulation					
stability	○	○	○	○	○

[Example 15]

The example was conducted in the same manner as Example 1 except that an alloy composition in which 1 weight part of Ag was added to 100 weight parts of the alloy composition of Example 1 was used as that of a fuse element.

A wire member for a fuse element of 300 $\mu\text{m}\phi$ was produced under conditions in which the area reduction per dice was 8% and the drawing speed was 80 m/min., and which are severer than those of the drawing process of a wire member for a fuse element in Example 1. However, no wire breakage occurred, and problems such as a constricted portion were not caused, with the result that the example exhibited excellent workability.

The solidus temperature was 79°C, and the maximum endothermic peak temperature and the fuse element temperature at an operation of a thermal fuse were lowered only by about 2°C as compared with those in Example 1. Namely, it was confirmed that the operating temperature and the melting characteristic can be held without being largely differentiated from those of Example 1.

In the same manner as Example 1, even when the overload test was conducted, the fuse element was able to operate without involving any physical damage such as destruction. Therefore, the fuse element was acceptable. With respect to the dielectric breakdown test after the opera-

tion, the insulation between lead conductors withstood $2 \times$ the rated voltage (500 V) for 1 min. or longer, and that between the lead conductors and a metal foil wrapped around the fuse body after the operation withstood $2 \times$ the rated voltage + 1,000 V (1,500 V) for 1 min. or longer. Therefore, the fuse element was acceptable. With respect to the insulation characteristic, the insulation resistance between the lead conductors when a DC voltage of $2 \times$ the rated voltage (500 V) was applied was 0.2 M Ω or higher, and that between the lead conductors and the metal foil wrapped around the fuse body after an operation was 2 M Ω or higher.

Both the resistances were acceptable, and hence the insulation stability was evaluated as O. Therefore, it was confirmed that, in spite of addition of Ag, the good overload characteristic and insulation stability can be held.

It was confirmed that the above-mentioned effects are obtained in the range of the addition amount of 0.1 to 3.5 weight parts of Ag.

In the case where the metal material of the lead conductors to be bonded, a thin film material, or a particulate metal material in the film electrode is Ag, it was confirmed that, when the same element or Ag is previously added as in the example, the metal material can be prevented from, after a fuse element is bonded, migrating into the fuse element with time by solid phase diffusion, and

local reduction or dispersion of the operating temperature due to the lowered melting point can be eliminated.

[0049]

[Examples 16 to 23]

5 The examples were conducted in the same manner as Example 1 except that an alloy composition in which 0.5 weight parts of respective one of Au, Cu, Ni, Pd, Pt, Ga, Ge, and Sb were added to 100 weight parts of the alloy composition of Example 1 was used as that of a fuse element.

10 It was confirmed that, in the same manner as the metal addition of Ag in Example 15, also the addition of Au, Cu, Ni, Pd, Pt, Ga, Ge, or Sb realizes excellent workability, the operating temperature and melting characteristic of Example 1 can be sufficiently ensured, the good overload
15 characteristic and insulation stability can be held, and solid phase diffusion between metal materials of the same kind can be suppressed.

 It was confirmed that the above-mentioned effects are obtained in the range of the addition amount of 0.1 to 3.5
20 weight parts of respective one of Au, Cu, Ni, Pd, Pt, Ga, Ge, and Sb.

[0050]

[Comparative Example 1]

 The comparative example was conducted in the same manner as Example 1 except that the composition of the fuse
25

element in Example 1 was changed to 42% Sn, 8% Bi, and the balance In.

The workability was satisfactory. Since the solid-liquid coexisting region is relatively narrow, dispersion
5 of the operating temperature was within the allowable range.

In the overload test, the fuse element operated without causing physical damage such as destruction. Therefore, the comparative example was acceptable.

10 In the dielectric breakdown test after an operation, however, the insulation between lead conductors was as low as 0.1 MΩ or lower. When a voltage of 2 × the rated voltage (500 V) was applied, re-conduction often occurred. Therefore, the insulation stability was ×.

15 The reason of this is estimated as follows. Although the fuse element is broken in the solid-liquid coexisting region, the region is relatively narrow, and hence the alloy during energization and temperature rise is rapidly changed from the solid phase to the liquid phase, thereby
20 causing an arc to be generated immediately after an operation. As a result, the flux is easily charred by a local and sudden temperature rise. Therefore, the insulation distance is shortened during an operation by the scattered alloy or the charred flux, and hence the insulation resis-
25 tance is low. As a result, when a voltage is applied, re-

conduction occurs to cause dielectric breakdown.

[0051]

[Comparative Example 2]

5 The comparative example was conducted in the same manner as Example 1 except that the composition of the fuse element in Example 1 was changed to 72% Sn, 8% Bi, and the balance In. The workability was satisfactory.

However, the operating temperature was $138 \pm 7^{\circ}\text{C}$, and the dispersion was larger than the allowable range of $\pm 5^{\circ}\text{C}$.

10 The reason of this is as follows. Although the solid-liquid coexisting region is wide, the melting rate in the coexisting region is so low that the division temperature of the fuse element cannot be concentrated. Results of the DSC measurement belong to the pattern of (C) of Fig. 11.

15 The solidus temperature is 121°C . This temperature is not always higher than (operating temperature - 20°C), and hence fails to satisfy the requirement of the holding temperature.

[0052]

20 [Comparative Example 3]

The comparative example was conducted in the same manner as Example 1 except that the composition of the fuse element in Example 1 was changed to 55% Sn and the balance In.

25 The workability was satisfactory, and the operating

temperature was dispersed in a small range, thereby causing no problem. In the overload test, the fuse element operated without causing physical damage such as destruction. Therefore, the comparative example was acceptable.

5 In the dielectric breakdown test after an operation, however, the insulation between lead conductors was as low as 0.1 MΩ or lower. When a voltage of 2 × the rated voltage (500 V) was applied, re-conduction often occurred. Therefore, the insulation stability was ×.

10 The reason of this is estimated as follows. Although the fuse element is broken in the solid-liquid coexisting region, the region is relatively narrow, and hence the alloy during energization and temperature rise is rapidly changed from the solid phase to the liquid phase, thereby
15 causing an arc to be generated immediately after an operation. As a result, the flux is easily charred by a local and sudden temperature rise. Therefore, the insulation distance is shortened by the scattered alloy or the charred flux, and hence the insulation resistance is low. As a re-
20 sult, when a voltage is applied, re-conduction occurs to cause dielectric breakdown.

[0053]

[Comparative Example 4]

The comparative example was conducted in the same manner as Example 1 except that the composition of the fuse
25

element in Example 1 was changed to 48% Sn, 2% Bi, and the balance In.

The workability was satisfactory. Since the solid-liquid coexisting region is relatively narrow, dispersion
5 of the operating temperature was within the allowable range. In the overload test, the fuse element operated without causing physical damage such as destruction. Therefore, the comparative example was acceptable.

In the dielectric breakdown test after an operation,
10 however, the insulation between lead conductors was as low as 0.1 MΩ or lower. When a voltage of 2 × the rated voltage (500 V) was applied, reconnection often occurred. Therefore, the insulation stability was ×.

The reason is identical with that of Comparative Exam-
15 ple 3.

[0054]

[Comparative Example 5]

The comparative example was conducted in the same manner as Example 1 except that the composition of the fuse
20 element in Example 1 was changed to 70% Sn, 15% Bi, and the balance In.

The workability was satisfactory. However, results of the DSC measurement belong to the pattern of (D) of Fig. 11, and the operating temperature was dispersed over the
25 range of about 150 to 165°C or at a large degree. The

solidus temperature is 139°C. This temperature is not always higher than (operating temperature - 20°C), and hence fails to satisfy the requirement of the holding temperature.

5 [0055]

According to the material for a fuse element and a thermal fuse of the invention, an alloy type thermal fuse having excellent overload characteristic, dielectric breakdown characteristic after an operation, and insulation
10 characteristic can be provided by using a Bi-In-Sn alloy which does not contain a metal harmful to a living body.

According to the material for a thermal fuse element of the second aspect of the invention and the thermal fuse, a fuse element can be easily thinned because of the excellent wire drawability of the material for a thermal fuse
15 element, and the thermal fuse can be advantageously miniaturized and thinned. Even in the case where an alloy type thermal fuse is configured by bonding a fuse element to a to-be-bonded material which may originally exert an influence,
20 a normal operation can be assured without impairing the functions of the fuse element.

According to the alloy type thermal fuses of the third to tenth aspects of the invention, particularly, the above effects can be assured in a thermal fuse of the cylindrical
25 case type, a thermal fuse of the substrate type, a thin

thermal fuse of the tape type, a thermal fuse having an electric heating element, and a thermal fuse or a thermal fuse having an electric heating element in which lead conductors are plated by Ag or the like, whereby the usefulness of such a thermal fuse or a thermal fuse having an electric heating element can be further enhanced.